Specific PVMaT R&D in CdTe Product Manufacturing

A. McMaster, K. Smigielski, C. Zarecki, J. Hanak, F. Borgeson, W. Monie
First Solar, LLC
28101 Cedar Park Blvd., Perrysburg, OH 43551

ABSTRACT

First Solar, with the support from the PVMaT program, has implemented an effort centered on three areas of work. The first area is called Manufacturing Line Improvements, which involved the design, construction and implementation of a high-speed laser scribing system capable of matching the throughput of a thin-film, solar cell manufacturing line of 20 MW/year. Significant increases in the reliability of equipment and decreases in the down time and capital costs were realized and an improved potting system was also developed. The second area is Product Readiness. This work focused on product safety and marketplace acceptance. The product was submitted for qualification testing that resulted in UL 1703 certification. The third work area consists of Environmental, Safety and Health Programs. Several programs are in place to maintain a healthy and safe work place. Planning has been completed on attaining ISO 14000 (or equivalent) certification.

1.0 Laser Scribing

Laser scribing of solar panels using thin-film solar cells is used for cell interconnections [1]. The objective of Phase III of this project was to develop a system for scribing solar panels, measuring 120 cm x 60 cm, with a throughput of one per minute, at a reduced capital cost, improved reliability, improved scribe control and requiring the use of a single laser beam per each of three types of scribes.

Traditional laser processing systems fall into two categories, using either a fixed head with an X-Y table, or a moving head. The first system's major drawback is the speed limitation of large X-Y tables, which is in the range of 300 to 500 mm/sec. The second system suffers from sizeable vibration caused by the rapidly moving head.

1.1 Improved Laser Scribing System

The system selected for this work is capable of achieving a 60-cm-long scribe line, having a minimum theoretical spot size of 70 microns. Scribe-to-scribe location is easy to control. The scribing can reach speeds in excess of 3400 mm/sec, requiring the use of pulsed lasers having a high rep-rate. A key benefit of this system is the ability to use a correction factor in the software, which allows cell mapping and correcting the focus for uneven surfaces.

1.2 Scribe Methodology

Traditionally, solar panels have been scribed from the coated side, which limits the scribing speed to 300 to 400 mm/sec, caused by the plume of vaporized material. This vapor absorbs the laser light and limits the power delivered to the scribe site. In order to achieve speeds in the range of 2000 mm/sec, scribing through the glass side of the solar panel, reported earlier [2], was pursued.

Green-light (532 nm) lasers are typically used for solar cell scribing in order to match the wavelength to the optical absorption of the material. In this project we made use of near-infrared (IR) lasers after determining that the CdTe absorption increases greatly with temperature for near-infrared (IR) wavelengths.

Considering the structure of the solar panels, from the sunny side, it consists of a soda-lime glass plate superstrate, coated with layers of TCO/CdS/CdTe/metal, encapsulated by a second plate of glass. The TCO signifies transparent conductive oxide. Because these layers have a decreasing energy gap in the same order, they require a decreasing amount of energy to be removed by scribing. Thus, the top-most layers can be removed at low energies without damaging the inner layers. Scribe-1 removes all the layers on the glass; scribe-2 removes the CdS and CdTe, without ablating the TCO. Scribe-3 removes the metal layer, applied after scribe-2; the metal is removed chiefly by the high-pressure CdTe vapor formed at its interface by the beam reflected by the metal. The relative scribing speeds for the three scribes are 1200, 2000 and 3000 mm/sec.

1.3 Sequential Function of the Scribing System

Each of the three scribing systems consist of a Load Station, Scribe Station and Unload Station.

The first phase of the Load system accepts the panels via manual loading by the operator. The scribe-1 station receives the panel from the Load Station and indexes it into the scribe location. Any curvatures in the panel are measured for calculating a factor to maintain focus over the entire panel. For scribe-2 and -3 the systems operate similarly, except that the fiducial marks, scribed during scribe-1, are read for position errors, to provide a correction factor for scribing.

The Unload Station receives the glass from each of the Scribe Stations by manual means. During phase 2 both the Load and Unload Stations will be automated.

1.4 Improvements Over Conventional Systems

The improvements with the improved scribing system include: (1) Reduced capital cost - the cost of high-speed improved laser system is about $300,000, while that of a conventional system, with four nozzles, is over $950,000; (2) reduced and lower-cost maintenance, which reduces down-time by a factor of ten; (3) greatly enhanced location accuracy of subsequent scribes through the use of fiducials, coupled with automated correction for panel growth/ shrinkage caused by temperature variations as well as panel rotation; (4) substantially reduced kerf widths and scribe spacing, whereby the active area of the panel is increased;

(5) IR lasers deliver about twice the power of frequency-doubled green lasers and have life expectancy of up to 10,000 hours, 14 times greater than green lasers, and lower cost; and (6) increased production throughput by a factor of four.

2.0 Qualification Testing of the Cord-Plate PV Module

One of the tasks of Phase III was to initiate and complete qualification testing of PV modules with new design. First Solar was to obtain IEEE 1262, IEC 1215, and UL 1703 certification for its modified module. As described in Section 2.1, the UL listing has been obtained.

In November 2000, fifteen modules were submitted for testing to the Photovoltaic Testing Laboratory (PTL) at the Arizona State University in Scottsdale, AZ, in accordance with the IEEE standards. The tests have been considerably successful. Two of the modules that were sent for IEEE testing failed the initial baseline wet leakage current measurement. The modules passed the humidity freeze and subsequent HiPot test. They decreased only 6% or less in power output through this sequence. The modules did not pass the entire battery of tests because one of the modules fractured during the static load test and two of the modules that were sent for IEEE testing failed the initial baseline wet leakage current measurement. Modifications have been made and new modules are being resubmitted for testing.

R&D activities that were conducted to facilitate the certification include: (a) heat strengthening of glass to avoid breakage; (b) failure time doubled through the use of a hot-melt pottant to extend the time to failure in the HiPot test, (c) relocation of the hole in the cover glass from 10 cm to 25 cm off the edge of the glass, thereby lowering the tensile stresses in the laminated module an average of 500 psi; (d) search for solutions to relatively high electrical conductivity of sodium-lime glass, now about 50% of the UL limit; (e) screening of alternative encapsulants to EVA to improve electrical insulation during damp-heat testing; (f) search for and damp-heat testing of alternative pottants to for use with the cordplate process; (g) removed bubbles around lead wires by using vacuum when applying sealant; (h) search for alternative pottant to silicone sealant around the wires or solder cavity to eliminate HiPot test failures; (i) changes in the process of injecting the pottant at higher pressure to the cord plates, resulting in longer survival times in HiPot tests; and (j) the automated HiPot station has been brought online.

A new engineering project has been initiated to achieve a robust cord-plate design/process. To date, a new understanding of the critical areas of this subsystem has been attained.

2.1 UL Listing of the First Solar PV Module

At the start of Phase III First Solar PV modules received a "recognition" from the Underwriter Laboratories, which allowed the modules to be used on listed mounting systems.

During April 2001, four modules have been resubmitted to the Arizona Testing Laboratory with a c-channel mounting system for HF-10 and static load testing. The tests were successful and First Solar received authorization to use the UL Listed mark on its FS-50c and FS-50z modules. These are complete modules with mounting attachments secured to the back side. The c and z designations indicate the style of mounting with the c denoting aluminum c-channel rails and the z denoting aluminum z-bar rails.

A package was submitted to the California Energy Commission to qualify for the CEC buy-down program, which was approved in August. First Solar was officially listed on their web site on 8 Aug. 2001.

3.0 Environmental, Health and Safety Programs

The objective of this activity was to continue to refine and improve the Environmental, Health and Safety (EH&S) programs by beginning activities related to obtaining ISO 14000 certification. During Phase III, 16 different activities have been completed to this end, which are listed below.

During the First Quarter the Company conducted procurement and vendor controls for environmental related purchases, identified equipment and chemical approval tracking, updated Emergency Response Plan, and developed a Disaster Recovery Plan.

During the Second Quarter we identified frequency and personnel involved with audit reviews and verification, audit procedure/compliance verification procedure, corrective action procedures for non-compliant items audit documentation, analyses of audit data, and audit reporting and management review.

During the Third Quarter we identified data collection and handling, data collection procedures, data interpretation procedures, and we monitored, maintained, and calibrated measuring equipment.

During the Fourth Quarter we developed procedures for recording and documentation control, conducted minimizing of discharges to air, water bodies, and sewer, implemented reduction of hazardous waste generation, and prepared to apply for ISO 14000 Certification, in conjunction with current efforts of First Solar with ISO 9000 compliance.

REFERENCES

[1] Joseph J. Hanak, "Laser Processing Technique for Fabricating Series-Connected Solar Cells into a Solar Battery," U.S. Patent 4,292,092, September 29, 1981.

[2] David Carlson et al., "Electrical Contacts for a Thin-Film Semiconductor Device," U.S. Patent 4,854,974, August 8, 1989.

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